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Research Article

SURFACE ROUGHNESS STUDIES OF FINGER PRINTS USING SPECKLE INTERFEROMETRY

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ABSTRACT

Measurement and control of surface roughness are important in many fields, such as magnetic media, semiconductor processing and optics. Typical roughness measurements are performed using stylus profilers, non-contact optical profilers, or scanning probe microscopes (SPM).An experimental approach for surface roughness evaluation based on the speckle pattern imaging has been attempted in this work by a simple configuration of setup consisting of laser, laboratory spectrometer, Beam Expander and CCD camera. The speckle image is processed by imageJ software and the surface parameters like skewness, kurtosis, histogram and correlation has been determined. The technique reported here has a great potential for precise and non-contact optical measurement of rough surfaces. (Akinoro Mouri *et al.,* 2002). The present study focuses on diffuse scattering and the corresponding speckle patterns obtained at different angles in the range 82^0 to 87^0 with an increment of one degree. Standard glass slides used as surfaces were imprinted with and without fingerprints in an attempt to study the influence of patterns. A correlation function (R) is defined for values of skewness, Kurtois and standard Deviations with and without finger prints for the same angles.

INTRODUCTION

Interferometric measurements of surface roughness are not so common destructive means of determining surface finish quality (Bennett and Mattsson, 1989). In interferometers which use a reference such as the Michelson, Mirau, Linnik, and Fizeau, the measurement yields the relative difference between the test and reference surfaces (Bhushan et al., 1985; Wyant et al., 1986; Biegen and Smythe, 1988). No surface is perfectly smooth (or or in other words, every surface have roughness).It depends on the Speckle produced when laser light is scattered off the rough surfaces. It appears as granular structures superimposed on the scene being viewed. The speckle pattern appears as an apparently random distribution of irregular patches of light or grains showing random intensity distributions. The size of speckle grains is proportional to the wavelength and viewing distance and inversely proportional to the aperture of the imaging detector. The intensity distribution and contrast of the speckle pattern can vary with the roughness of the surface being illuminated (Shiraishi and Sato, 1991). The properties of speckle pattern are determined by the light source, the rough surface, and the optical probing technique.

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Two slightly different speckle patterns can be used to measure surface roughness parameters like standard deviation, kurtosis, skewness etc, since these parameters depends on the variance of the surface height distribution. The two speckle patterns are produced by illuminating a rough surface with coherent light at two different angles of incidence. For doing this we designed a stepper motor card for automated rotation and attached the stepper motor to conventional spectrometer. The steeper motor card controls the Detector arm for precise automatic rotation of CCD. This setup can be used to find out the surface roughness of the given sample. Image obtained from the CCD are processed using ImageJ Program to analyse the images.

MATERIALS AND METHODS

When a rough surface is illuminated by a laser beam, the diffused light gives a granular pattern, because of the random spatial variation of intensity. This phenomenon is called ‘‘speckle’’ and is characteristic of coherence and of any laser source. A typical configuration producing image speckles is shown schematically in Fig. 1.

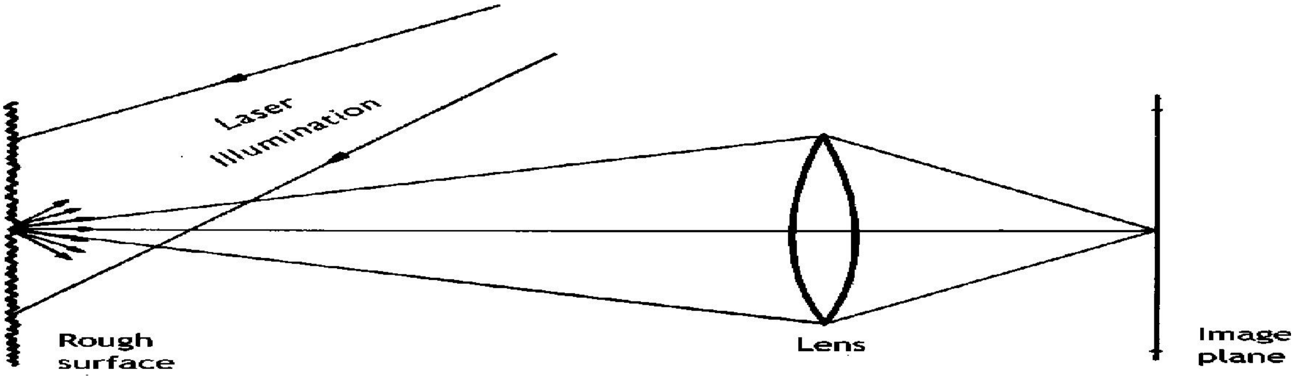


Fig. 1. Formation of image speckles

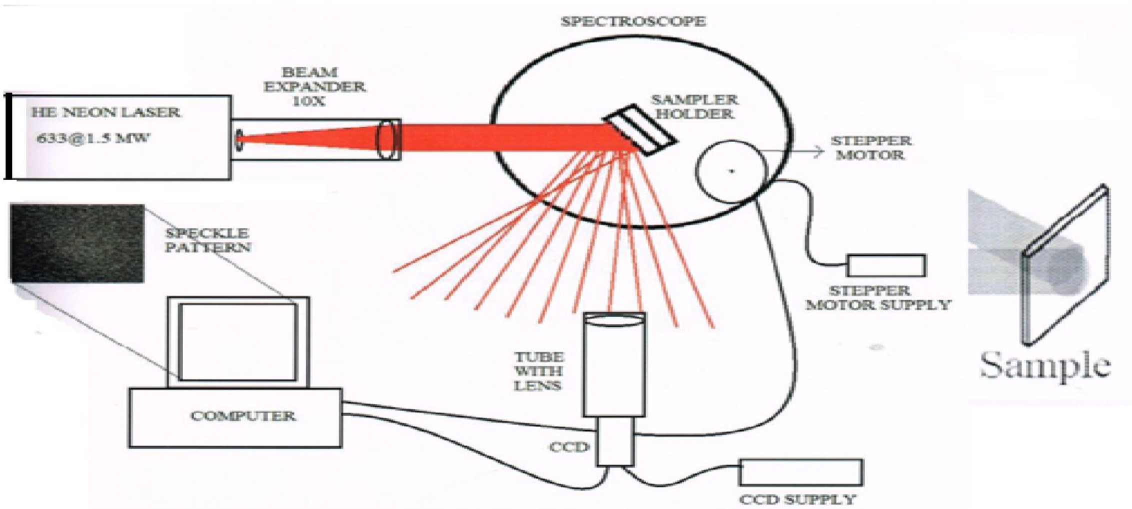


Figure 2. The Schematic diagram of experimental setup (Kapil Singh Kundu, 2002)

Standerd Defenisions For Urface Roughness

Skewness

Skewness is a measure of symmetry, or more precisely, the lack of symmetry. A distribution, or data set, is symmetric if it looks the same to the left and right of the center point.

$R_{sk=}$ 1/ [$nR_q^3 \sum_{i=1}^{n} y_i^3$]…………………………………………..(1)

Kurtosis

Kurtosis is a measure of whether the data are peaked or flat relative to a normal distribution.

$R_{ku=}$ 1/ [$nR_q^4 \sum_{i=1}^{n} y_i^4$]…………………………………..…..(2)

Histogram

In statistics, a histogram is a graphical representation showing a visual impression of the distribution of data. It is an estimate of the probability distribution of a continuous variable. The Histogram is an effective graphical technique for showing both the skewness and kurtosis of data set. Histograms are used to plot density of data, and often for density estimation: estimating the probability density function of the underlying variable. The total area of a histogram used for probability density is always normalized to 1.

If the length of the intervals on the x-axis is small, then a histogram is identical to a relative frequency plot.

Correlation

The correlation (R) is obtained by using the statistical equation

$$R=\frac{\sum xy-(\sum x)(\sum y)}{\sqrt{(N\sum x^2)-(\sum x)^2(n\sum y^2-(\sum y)^2}}$$ ……………..………………(3)

Where: N- No. of pairs of scores

∑xy- sum of the products of paired scores
∑x- sum of x scores
∑y- sum of y scores

Optical Instrumenation and Devices

The components of the setup are as follow

- Helium Neon laser (633nm@1 .5MW) of Research electro-optics.
- Beam expander has 20X magnification.
- Collimating Arm with focusing lens**:** has length of minimum of 15 cm and can be increased if required up to 20 cm.
- Detector Arm with focusing Lens , Iris and CCD

- CCD specifications used. (CP PLUS, CP-RAC, BY-48)
- Pixel PAL: 537H*597V, NTSC: 537H*505V Resolution 480TVL
- *Interfacing card and stepper motor*
  This card is an interface between computer and motor.
- *Glass sample* (Glass slide (Blue Star micro slides of 75mm X 25mm) and Optical flat).
-

Experimental Set Up

The optics used in the setup are crucial in collimating and focusing the laser beam. In this setup 3 lenses are used.The first two were used as telescopic lenses to collimate the beam with 20X magnification (in the Collimating Arm) and third one (with f=18cm) is used to focus the scattering light on CCD (in the Detector Arm) which is fixed within the Detector Arm. Standard Glass is oriented in sample holder with the laser beam making an angle of 45^0 with sample holder. Now the readings are taken at different angles for the analysis purpose. The rotation of CCD and speed of rotation is controlled with help of program (which is burnt in d basic macros). In each step 1^0 of rotation is generally used. Here, as the CCD rotates around the sample, the images of speckle pattern are recorded on to the hard disk of computer. It is shown in Fig. 2.

Scans and Their Analysis

Speckle Patterns and Their Histograms

In this section, the patterns obtained with glass slides, with and without finger prints are used to take speckle interferrogram by using unpolarized light He-Ne laser. The figures given below shows the speckle patterns along with its histogram for angles varying from 82^0 to 86^0.He-Ne laser is used because of its gaussian profile. Unplolarized light is used as a scattering process can cause polarizartion in the scattered light and thus diminishing the image.

Fig. 3.1(a) Speckle pattern of glass slide at angle 86^0

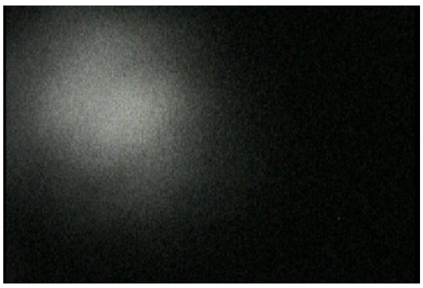


Fig. 3.2.(a) Speckle pattern of glass slide with Finger print at angle 86^0

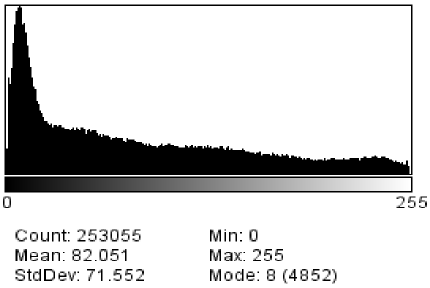


Fig. 3.1(b) Histogram of fig-3.1(a)

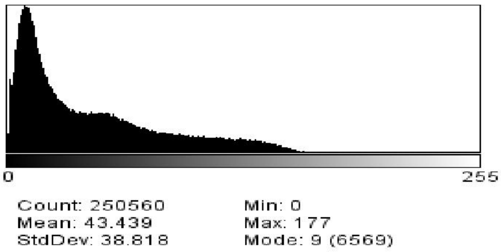


Fig. 3.2(b) Histogram of fig-3.2(a)

Fig. 3.3(a)Speckle pattern of glass slide at angle 85^0

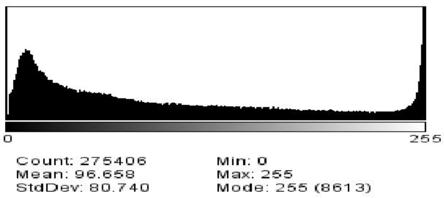


Fig-3.3 (b) Histogram of fig-3.3(a)

Fig. 3.4(a) Speckle pattern of glass slide with Fingerprint at angle 85^0

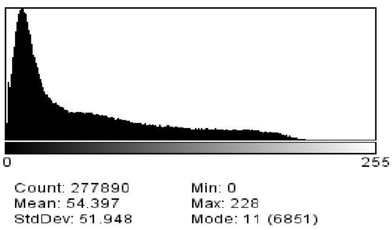


Fig. 3.4(b) Histogram of fig-3.4(a)

Fig. 3.5(a) Speckle pattern of glass slide at angle 84^0

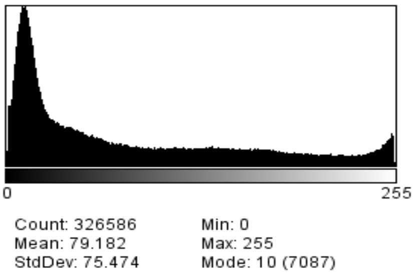


Fig. 3.5(b) Histogram of fig-3.5(a)

Fig. 3.6(a) Speckle pattern of glass slide with Finger print at angle 84^0

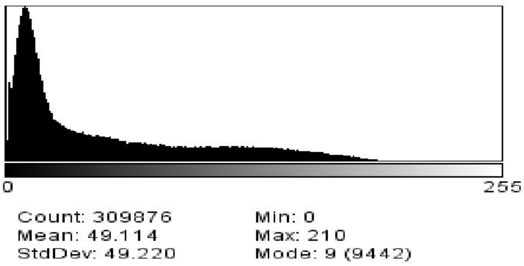


Fig-3.6(b) Histogram of fig-3.6(a)

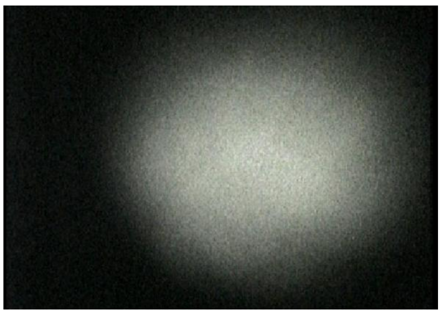


Fig.3.7(a) Speckle pattern of glass slide at angle 83^0

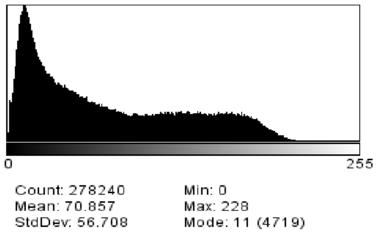


Fig. 3.7(b) Histogram of fig-3.7(a)

Fig-3.8(a) Speckle pattern of glass slide with Fingerprint at angle 83^0

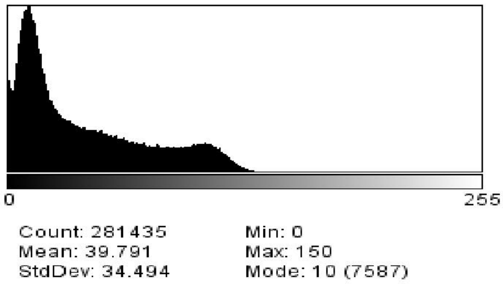


Fig. 3.8(b) Histogram of fig-3.8(a)

Fig. 3.9(a) Speckle pattern of glass slide at angle 82^0

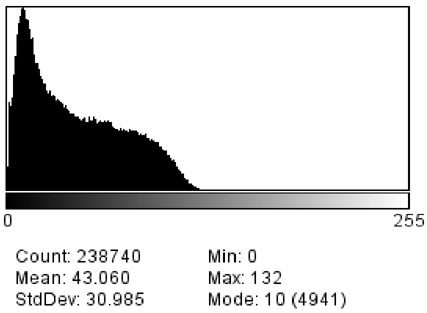


Fig. 3.9(b) Histogram of fig-3.9(a)

Fig. 3.10(a) Speckle pattern of glass slide with

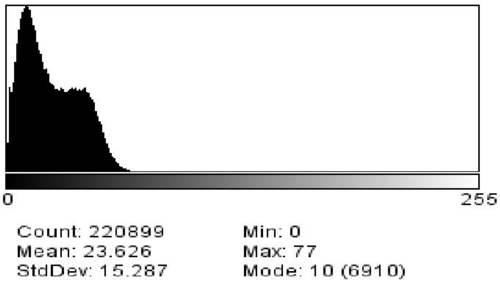
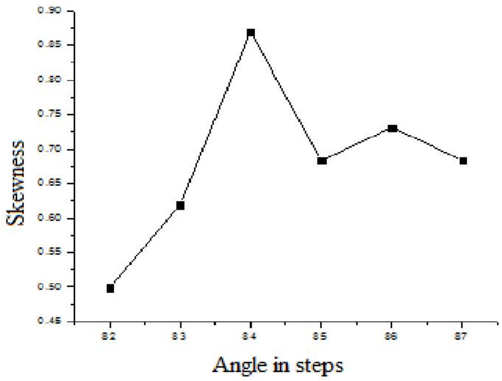
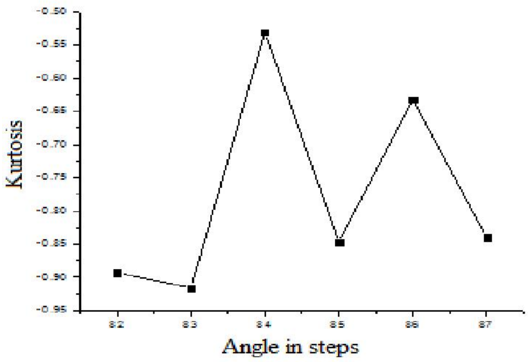


Fig. 3.10(b) Histogram of fig-3.10(a)
Fingerprint at angle 82^0

Plots of Skewness, Kurtosis and Standard Deviation

In order to study the speckle patterns statistically, we have computed the Skewness, Kurtosis and standard deviation using the ImageJ program for different angles from 82 degrees to 87 degrees. These statistical parameters have been computed for a). With out finger prints on standard glass slides b). With fingerprints.





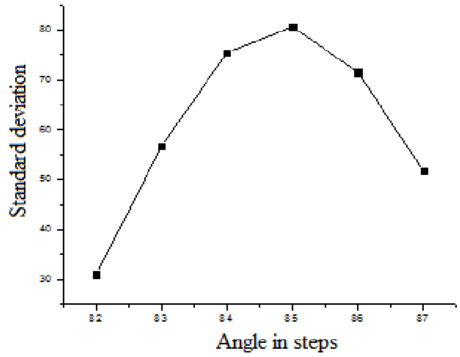
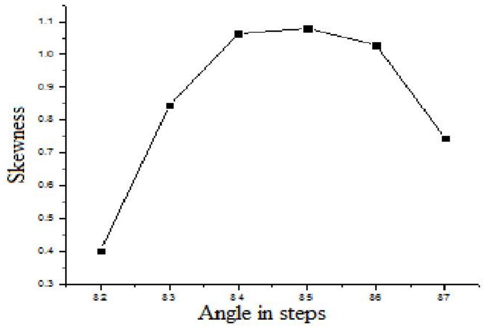
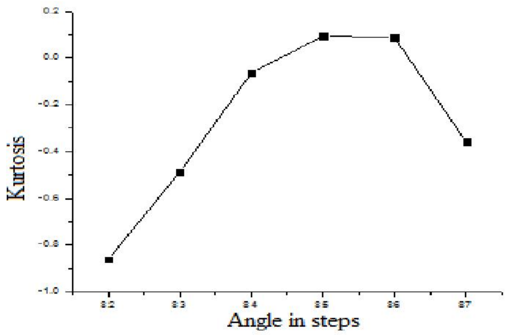


Fig.4. Plots of Skewness, kurtosis and standard deviation respectively of glass slide without finger print with He-Ne laser

Fig.4 shows the plots of Skewness, Kurtosis and standard deviation respectively of glass slide without finger print taken using He-Ne laser. Fig: 5 depict the same parameters with finger prints on the glass slides





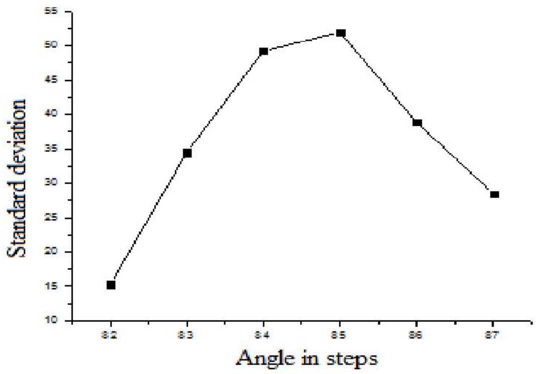


Fig. 5. Plots of Skewness, Kurtosis and Standard Deviation respectively of glass slide with finger prints taken using He-Ne laser

Correlation Plots

The plots obtained after the analysis of correlation of statistical parameters of speckle patterns at the same angle, but with fingerprint and without finger prints are shown in Fig. 6.

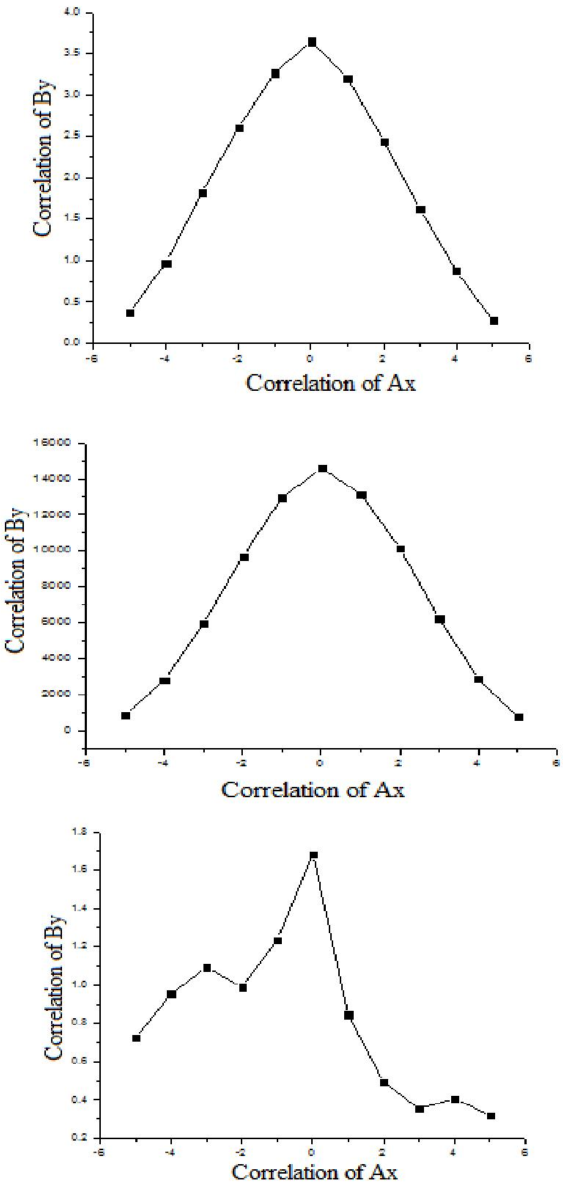


Fig.6.Plots of Correlation of Skewness, Kurtosis and standard deviation respectively of glass slide with/without finger print with He-Ne laser

The correlation(R) has been calculated using equation: 3.

Conclution

The present work is an attempt to study systematically the roughness created by figure printsmade on glass slides. The instrumentation part is being designed from laboratory available components like spectrometer, CCD, laser collimator, desktop PC; stepper motor etc.

The speckle instrument is much similar to conventional scattering setup. Angles could be automatically moved in steps set and controlled by computer. An ImageJ software is used which has options to calculate the roughness parameter like standard deviation; Kurtosis and Skewness at different angles. Also values of correlation between patterns determined. This technique if extended would be useful in pattern reorganization.

REFERENCES

Akinoro Mouri, Nobuya Aoki, Takahiko Inari, 2002. “Surface Roughness Measurement Using Laser Diffraction Pattern Obtained by a Video Camera and Photo Sensors” SICE 2002, Aug 5-7-2002, Osaka, . 2517-2519.

Bennett, J.M. and Mattsson, L. 1989. Introduction to Surface Roughness and Scattering, Optical Society of America, Washington, DC.

Bhushan, B., Wyant, J.C. and Koliopoulos, C.L. 1985. Measurement of Surface Topography of Magnetic Tapes by Mirau Interferometry, *Appl. Opt.*, 24, 1489-1497.

Biegen, J.F. and Smythe, R.A. 1988. High Resolution Phase Measuring Laser Interferometric Microscope for Engineering Surface Metrology, in Proceedings, Fourth International Conference on Metrology and Properties of Engineering Surfaces (National Bureau of Standards, Washington, DC), 13-15.

Kapil Singh Kundu, 2002. M.Tech thesis in (GJUS&T Hisar) “Surface Roughness Measurement Using Laser Speckle” unpublished.

Shiraishi, M. and Sato, K. 1991. Possibility of Large Roughness Measurement by Laser Speckle Transaction of the ASME, Vol 113, 476

Wyant, J.C. Kolipoulos, C.L. Bhushan, B. and Basila, D.1986. Development of a Three-Dimensional Noncontact Digital Optical Profiler, Trans. ASME, J.Tribol.108, 1-8.

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